Accelerated Aging and Life Time Prediction for Solar Concentrators

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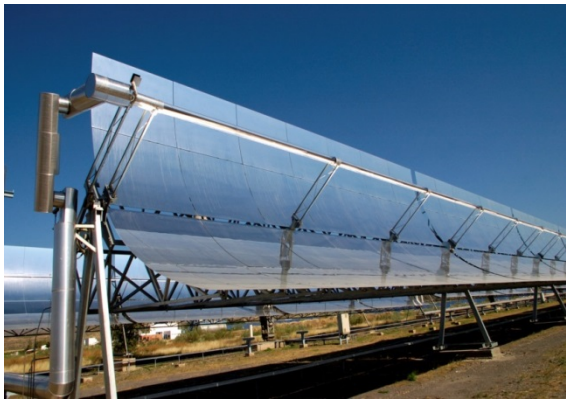
- Motivation/Solar mirrors
- Outdoor testing
- Accelerated laboratory testing
- Standardization of testing procedures
- Methodology to correlate accelerated aging of aluminum reflectors with outdoor exposure

Motivation

- Durability of CSP components crucial for success of the technology
- Solar field and reflectors are responsible for a considerable amount of investment costs
- Life time prediction is important for planning of projects (life time goals 20 years and more)
- So far few standards exist and are not adapted for CSP technology

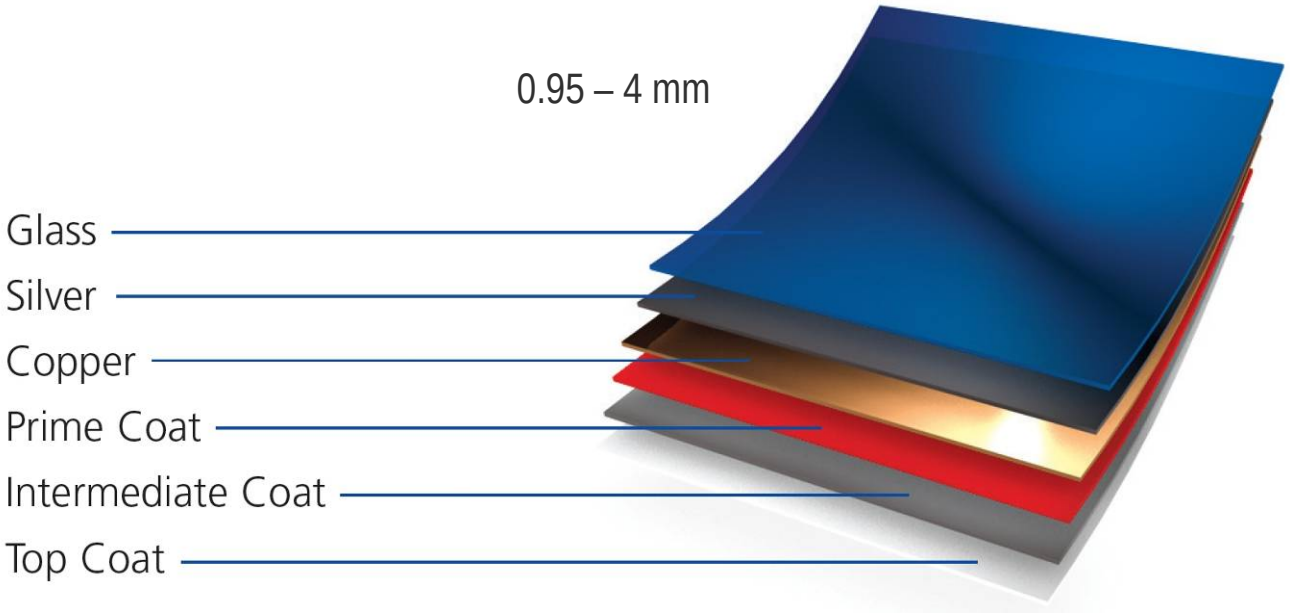


OPAC laboratory

- Optical Aging Characterization Laboratory
- Joint project DLR/CIEMAT at the Plataforma Solar de Almería
- Fields of work:
  - Optical characterization
  - Durability, Aging, Life time prediction

Glass mirrors

- Most common reflector
- Experience from over 30 years, excellent stability
- High specular reflectance
- New lead free, water soluble paints need to prove durability



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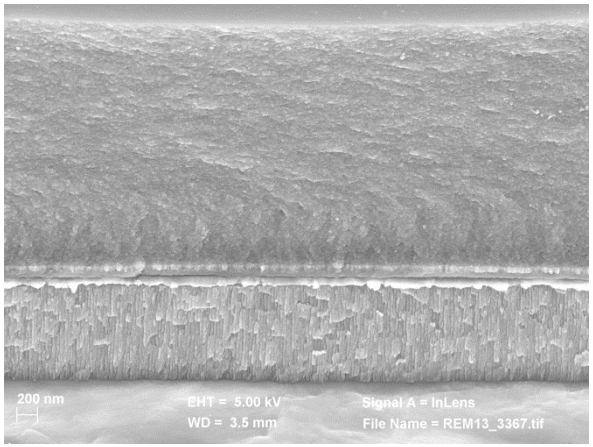
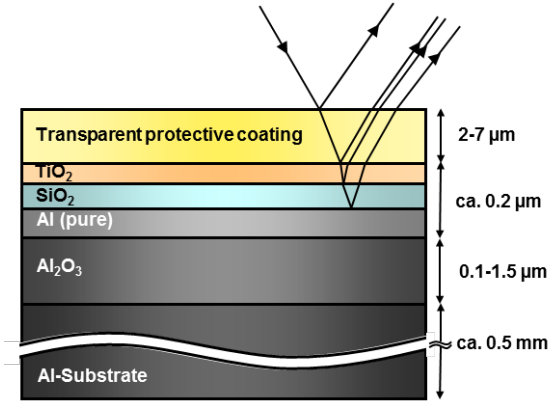
Alternative reflectors

Aluminum mirrors

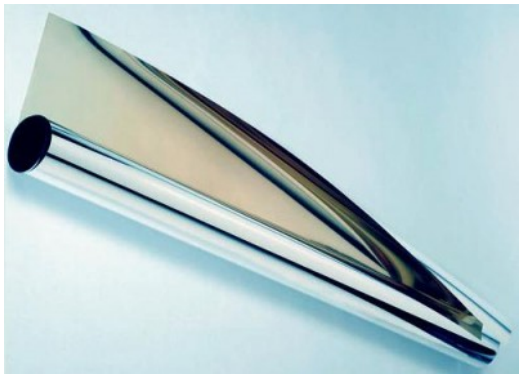
- Thin, light weight, flexible
- Lower reflectance
- Durability issues

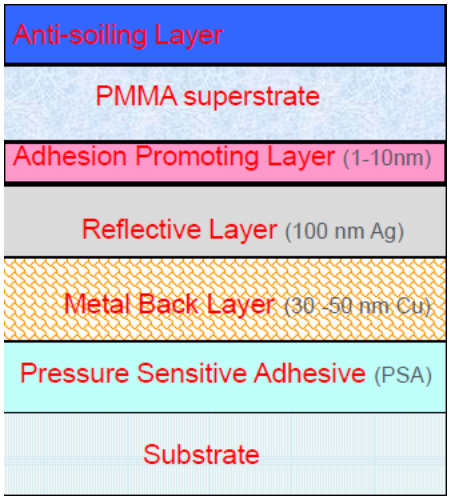




Polymer films

- Thin, light weight
- Good reflectance, lower specularity
- Less experience

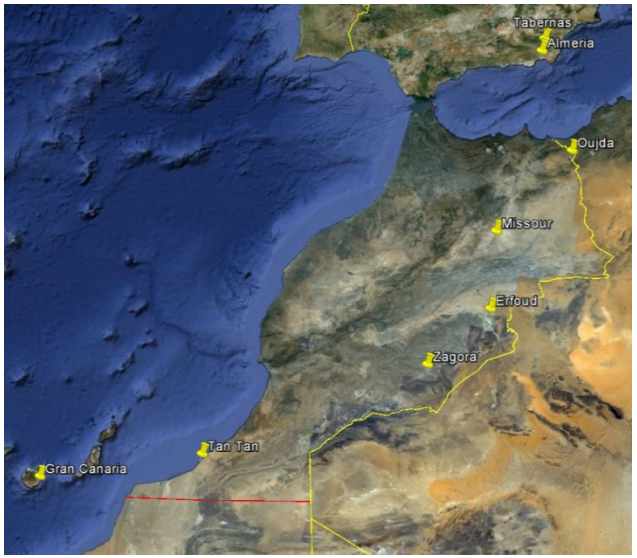




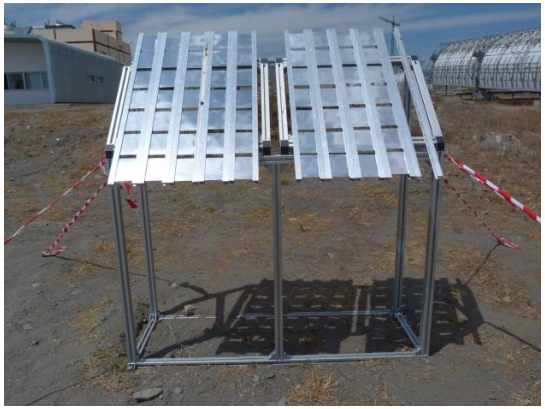
[NREL]

Outdoor Exposure

- Extensive outdoor exposure campaign (10 sites)
- Almeria, Tabernas, Gran Canaria, Abu Dhabi, Oujda Missour, Erfoud, Zagora, Tan Tan, Ben Guerir
- More sites planned, or from cooperating institutions
- Variety of site conditions, from urban over coastal to desert

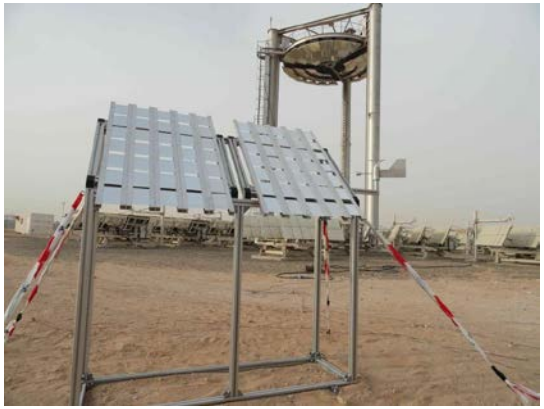


Exposure sites



Tabernas, PSA

Almería



Masdar, Abu Dhabi

Las Palmas

Oujda

Missour

Exposure sites

Erfoud

Zagora

Tan Tan

Ben Guerir

Outdoor conditions

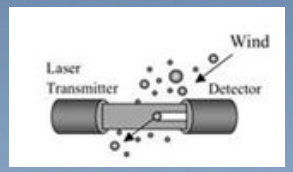
Measurement of important site characteristic data:

- Temperature
- Humidity
- Irradiation
- Wind
- Particles, Sand, Dust
- Chlorides
- Other pollutants, compounds

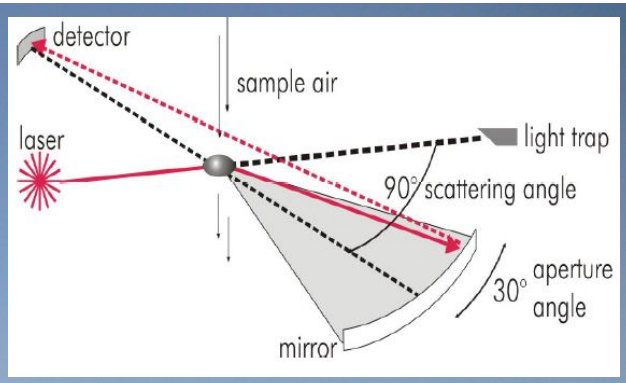
Field data Missour – particle measurements

Light barrier attached to mirror in 5 different heights

>40µm



Visibility sensor



Filter particle sampler **TSP**

0.25-31µm

Grimm particle sensor

DustTrak **0.1-10µm**

Accelerated Testing

- Laboratory tests try to provoke aging in accelerated but realistic way
- By choosing more severe parameters:
  - Temperature
  - Humidity
  - Irradiance (UV)
  - Cycles
  - Chemicals, pollutants (NaCl, acids, soiling)
  - Abrasion (particles, brushes)

Accelerated Laboratory Tests

Standard tests

- NSS (ISO 9227)
- CASS (ISO 9227)
- Damp Heat (IEC 62108)
- UV/Humidity (ISO 11507)
- Humidity Freeze (IEC 62108)
- Kesternich (DIN 50018)
- UV Test
- Machu Test
- Immersion Test

Combinations/advanced tests

- NSS + UV/humidity
- NSS + Artificial Soiling
- Damp Heat + Artificial Soling
- UV/Humidity + Artificial Soiling
- Humidity Freeze + Artificial Soiling
- CASS + Sand Abrasion
- NSS + Sand Abrasion
- UV/humidity + Sand Abrasion

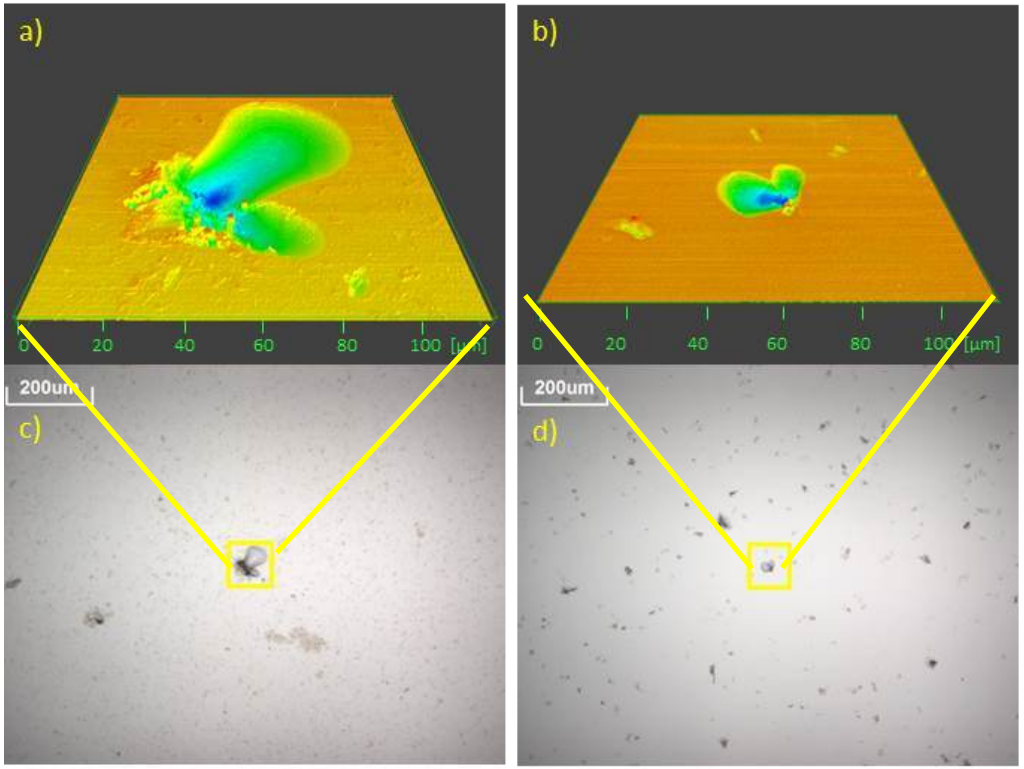
Challenge: find the best suited tests and parameters

Laboratory erosion setup I: Soil Pipe (SP)

Used abrasive material: Silica particles with diameters between 300-625 µm.

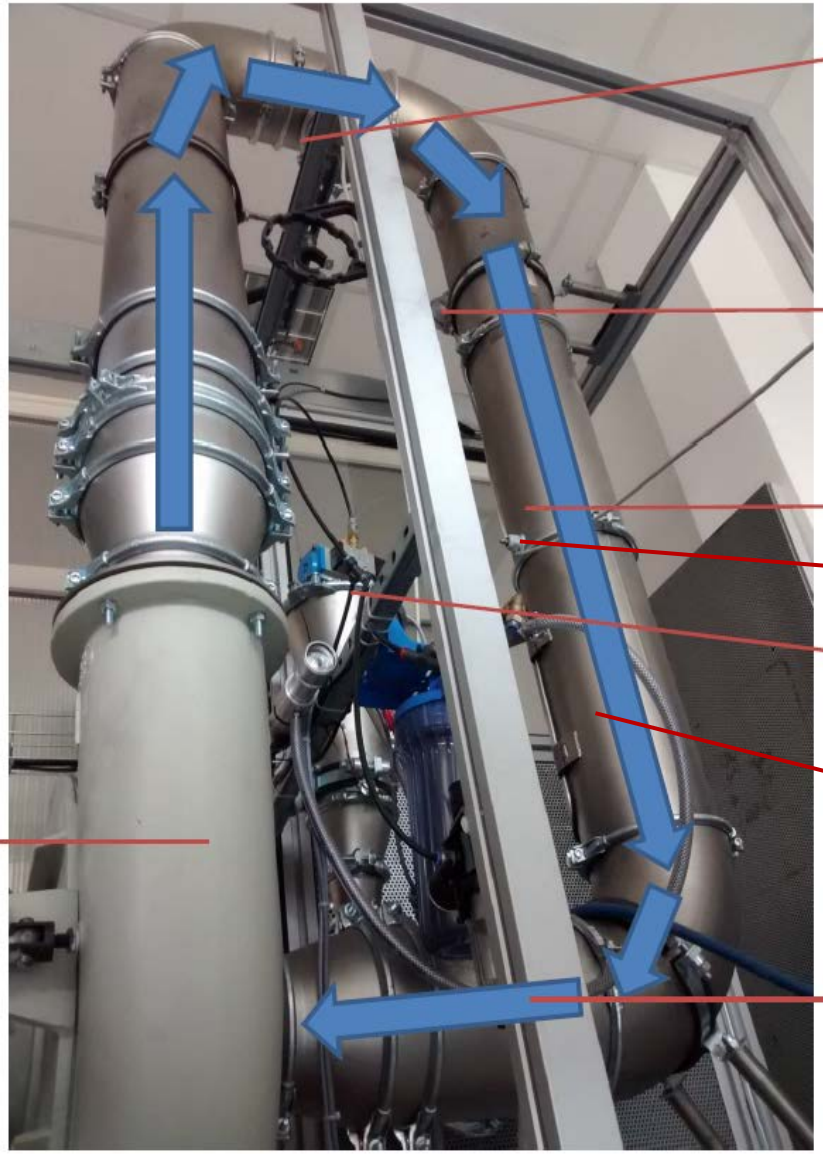
Outdoor - Zagora

Laboratory – soil pipe



Wiesinger et al. *Sand erosion on solar reflectors: accelerated simulation and comparison with field data* DOI 10.1016/j.solmat.2015.10.036

Laboratory erosion setup II: Sand Storm Chamber (SSC)



Ultrasonic wind sensor

Inductive particle concentration measurement

Flow rectifier and particle mixer

Connection for gravimetric particle measurement

Dust injection system

Sample compartment

Fan blower

Return flow in blower

Technical parameters:

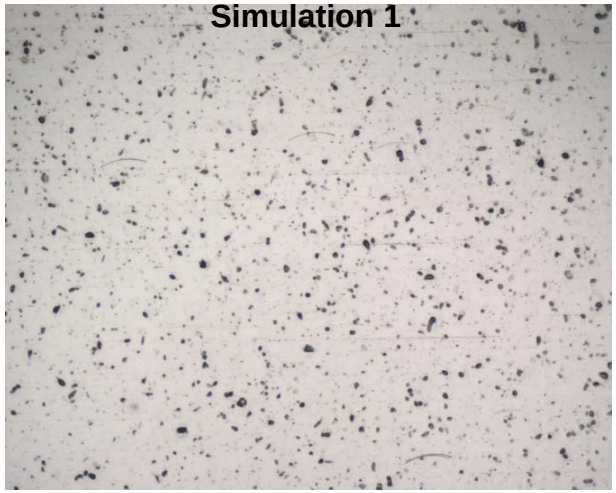
- Wind velocities from 5 ms^{-1} to 30 ms^{-1}.
- Dust concentration from 50 mg m^{-3} to 3000 mg m^{-3}.
- ISO 12103-1 A4 Arizona Quartz dust (1- 180 µm).

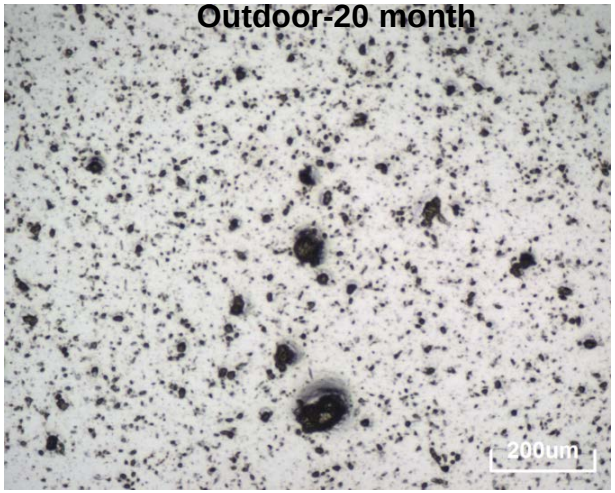
Combination of SSC and SP on Aluminum reflector

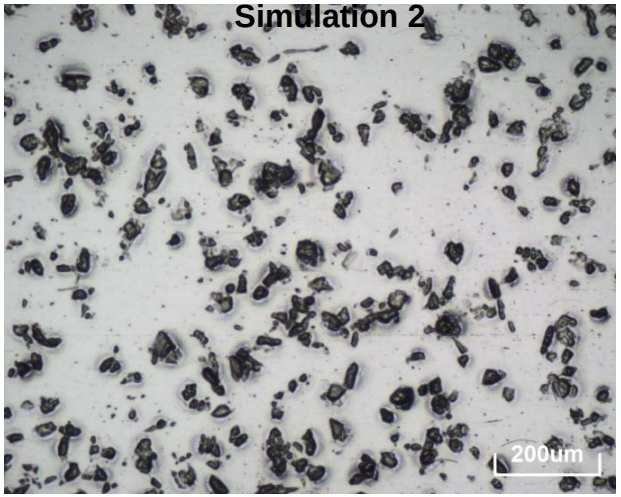
SSC

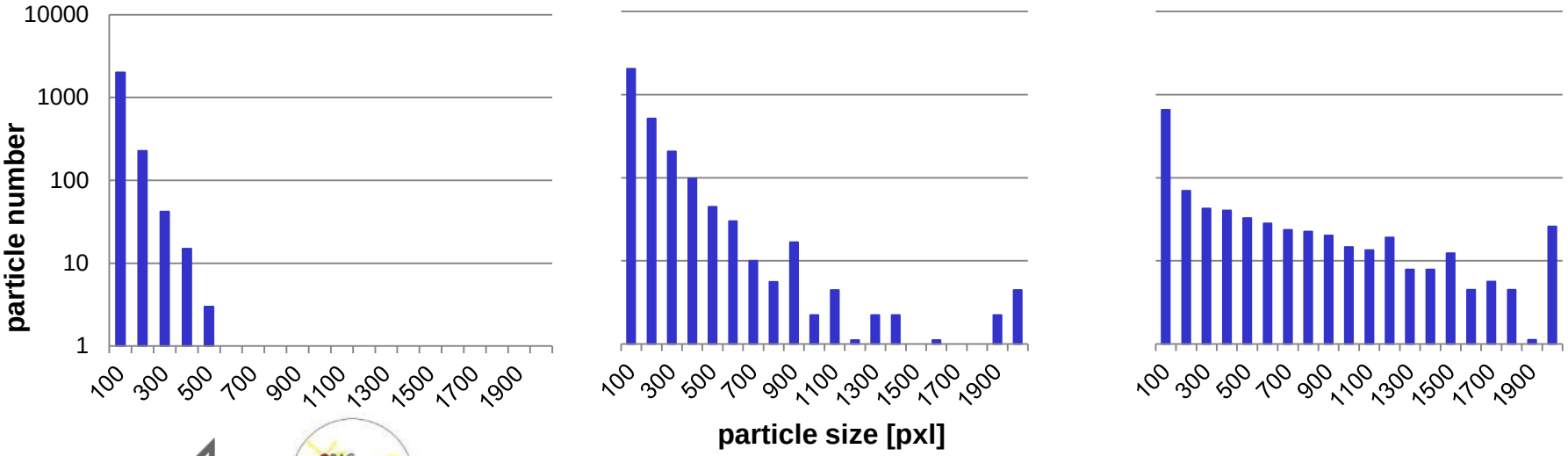
Zagora

Soil Pipe







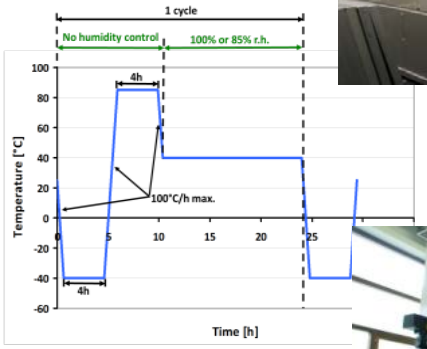


Standardization/Lifetime prediction

- AENOR (Spanish standardization agency) developed a standard with minimum requirements for glass mirrors

- ***Reflectance and shape*** (guidelines from SolarPACES Task III)

- ***Ageing tests***
  - *Exposure to neutral salt spray test (NSS)*
  - *Exposure to copper accelerated acetic acid salt spray (CASS)*
  - *Condensation test*
  - *Cyclical exposure to temperature and humidity*
  - *UV radiation exposure test*



- ***Mechanical durability resistance***
  - *Mechanical tests*
  - *Abrasion resistance test*
  - *Impact resistance test*
  - *Safety performance under accidental impact test*

Alumir Project

- Main goal: **Development of an accelerated aging guideline for aluminum solar reflectors**
- Funded by German Federal Ministry for Economic Affairs and Energy
- Extensive outdoor testing campaign
- Accelerated laboratory tests
- 9 materials from 3 manufacturers
- 9 outdoor sites

Testing of 9 material types

Microscopic comparison of degradation mechanism

Selection of most realistic accelerated tests

Develop correlations for each mechanism individually

Definition of testing sequence and parameters (testing times)

Guideline for durability testing of aluminum reflectors

Outdoor exposure

Tabernas, ES
Almería, ES
Gran Canaria, ES
Oujda, MA
Erfoud, MA
Missour, MA
Zagora, MA
Tan Tan, MA
Abu Dhabi, UAE

Accelerated aging

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CASS (ISO 9227)
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UV Test
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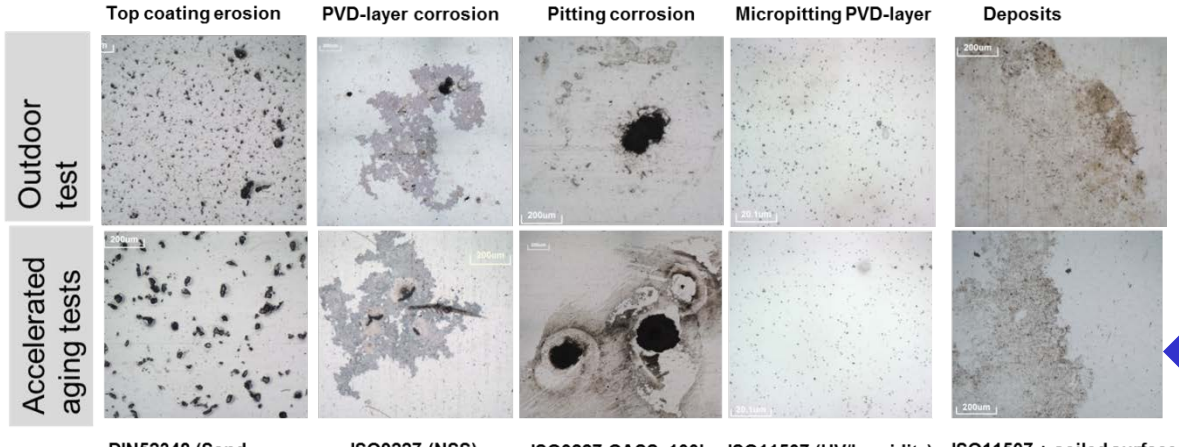
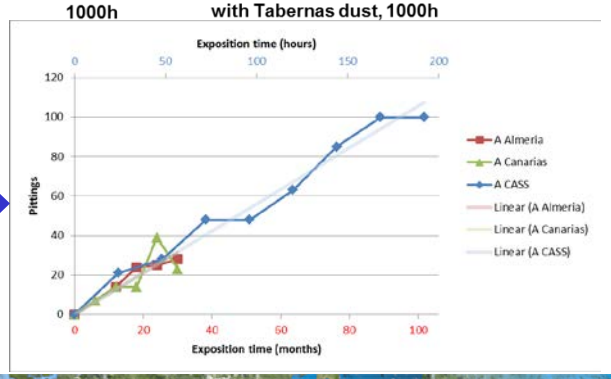
NSS + Artificial Soiling
Damp Heat + Artificial Soling
UV/Humidity + Artificial Soiling
Humidity Freeze + Artificial Soiling
CASS + Sand Abrasion
NSS + Sand Abrasion
UV/humidity + Sand Abrasion

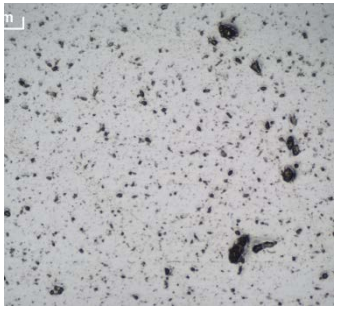
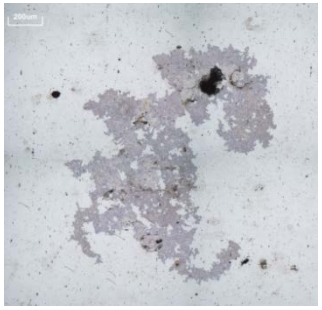
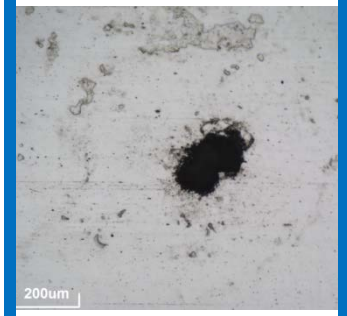
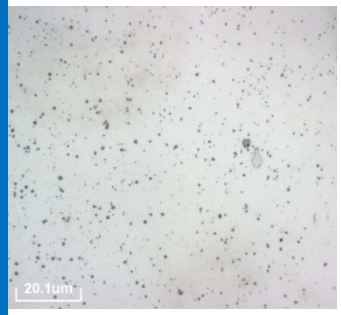
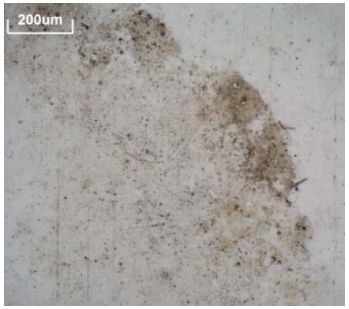
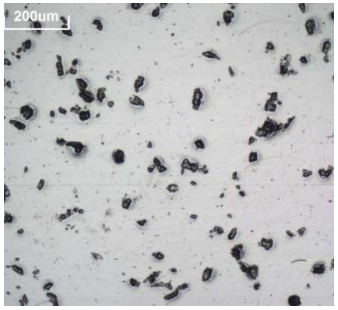
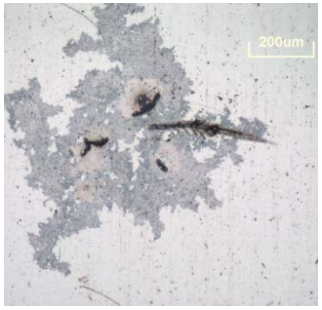
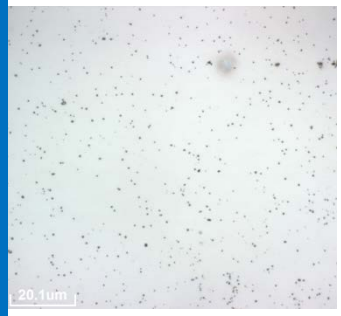
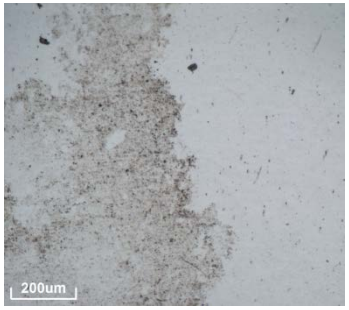




DLR

OPAC

Correlating Accelerated Aging to Outdoor Exposure Tests

	Top coating erosion	PVD-layer corrosion	Pitting corrosion	Micropitting PVD-layer	Deposits
Outdoor test					
Accelerated aging tests					
	DIN52348 (Sand trickling test) Silica 300-650 µm	**ISO9227 (NSS), 1000h**	**ISO9227 CASS, 100h**	**ISO11507 (UV/humidity), 1000h**	**ISO11507 + soiled surface with Tabernas dust, 1000h**

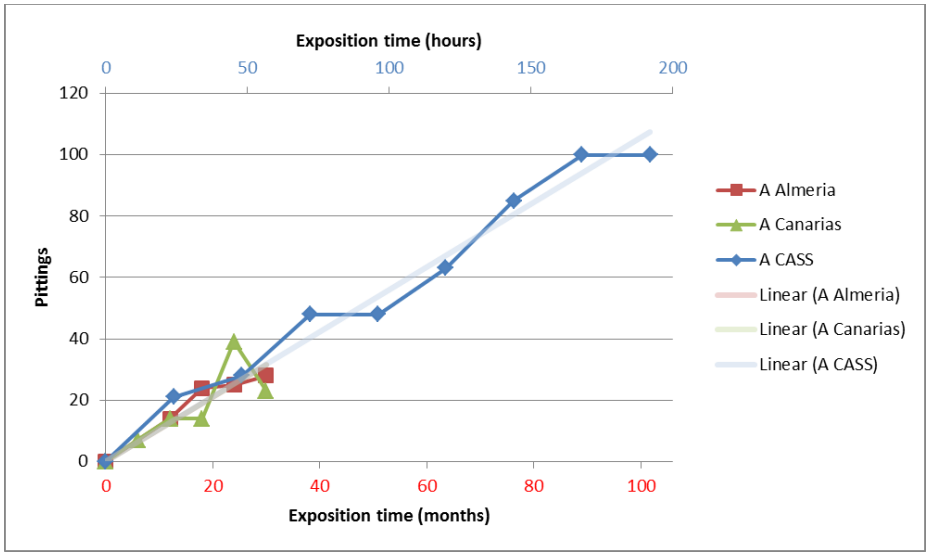
Degradation Mechanism: Pitting Corrosion

Simulated by: **CASS (ISO9227)**

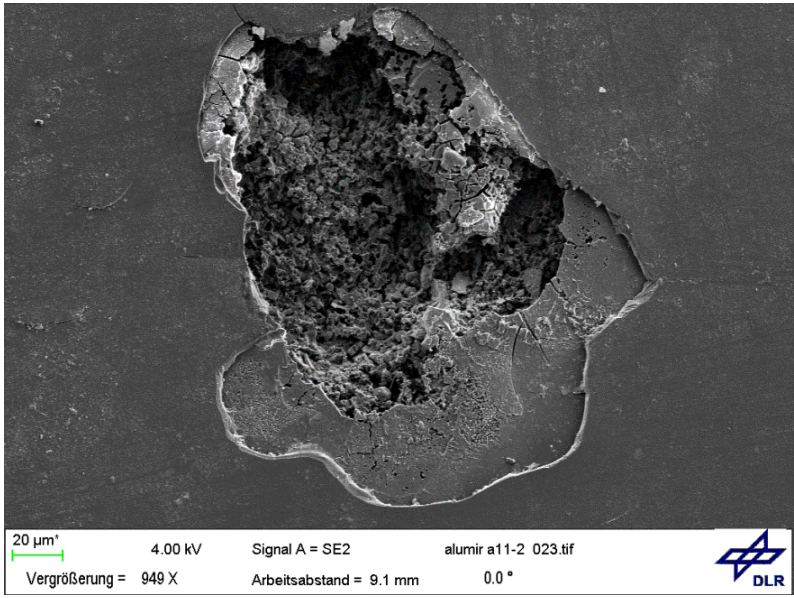
Correlation parameter: **Number of corrosion pits**

Equipment: **Counting by eye / optical microscope**

Correlation to outdoors:



Pitting corrosion (viewed in SEM)



Site	Months	CASS time (h)
Extreme desert (Zagora)	20	-
	36	-
	60	-
	120	-
Desert (Missour, Erfoud, Oujda, Tabernas)	36	-
	60	-
	120	-
Coastal (Almeria, Tan Tan, Gran Canaria, Abu Dhabi)	36	94
	60	156
	120	312

Accelerated aging procedure of aluminum reflectors

Mechanism		Pitting	Top coating erosion	PVD-corrosion	Micropitting	Typical specular reflectance loss @ 660nm, 12.5mrad
Site	Months	CASS (h)	Sand trickling (g)	CASS (h)	UV/humidity (h)	
Extreme Desert	20	-	100	1	480	(20%)*
	36	-	180	2	480	12% (45%)*
	60	-	300	4	480	-
	120	-	600	8	480	39%
Desert	36	-	10	10	480	5%** (5%)*
	60	-	15	15	480	-
	120	-	30	30	480	-
Coastal site	36	94	10	12	480	6% (5%)*
	60	156	10	20	480	-
	120	312	10	40	480	27%

*Measured/estimated average outdoor values in brackets

** estimated value based on slightly modified procedure

Summary

- Durability tests/Lifetime prediction of components is crucial
- Testing/Outdoor exposure infrastructure exists
- Standardization is an ongoing task
- Standard with minimum requirements for glass mirrors exists
- Guideline with site-specific tests for aluminum reflectors was developed and is under research for reflectors in general

Thank your for your attention!

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